Mausam, (1993), **44**, 2, 147-152

551.577.3 : 556.18(213.52)

Analysis of rainfall data for water management in dry land zone of Karnataka

R. N. ADHIKARI, M. S. RAMA MOHAN RAO and P. BHASKAR RAO

Central Soil & Water Conservation Research & Training Institute,

Research Centre, Bellary, Karnataka

(*Received 7 January 1992, Modified 28 July 1992*)

सार — कर्नाटक के अर्ध-शुष्क क्षेत्रों में बिल्लारी नामक प्रदेश में 35 वर्षा दिवसों में केवल 508 मि॰ मी॰ वार्षिक वर्षा होती है।

वर्षा के विषय वितरण से प्रत्येक दशक में कम से कम 5 अनॉवृष्टि (सूखे) वर्ष होते हैं। वर्षा के औसत वितरण से पता चलता है कि खरीफ की फसल के समय वर्षा बिलकुल नही होती है। तथापि, सितम्बर और अक्तूबर में कुछ निश्चित वर्षा होती है जिसे रबी की फसल के लिए अच्छा माना जाता है। फसलों और जल के वैज्ञानिक प्रबंध से इस समस्या को कुछ हद तक हल किया जा सकता है। इसके लिए किसी भी महत्वपूर्ण जल स्रोत की समस्याओं के बारे में विस्तृत विश्लेषण की आवश्यकता है। इस बात को ध्यान में रखते हुए इस शोध पत्र में वर्षा के अल्पावधिक तथा दीर्घावधिक आंकड़ों का विश्लेषण करने का प्रयास किया गया है। बुवाई के लिए उपयुक्त समय की पहचान करने के लिए अल्प अवधियों की वर्षा की शायिकता का विश्लेषण, मृदा और जल संरक्षण संरचनाओं के अभिकल्पन तथा भंडारण, संरचनाओं के आकार का निर्धारण करने के लिए प्रत्यागमन काल विश्लेषण, फसल तथा जल प्रबंध हेतु जल एकत्रित करने की प्रणाली की अभिकल्पना के लिए वर्षा की विभिन्न घटनाओं की पहचान की गई और उनका उल्लेख इस शोध में किया गया है।

इस अध्ययन के परिणाम कर्नाटक के कृषि जलवायु क्षेत्रों तथा इसके समान अन्य क्षेत्रों में जल संभर प्रबंध परियोजना की आयोजना में सहायक होंगे।

ABSTRACT. Bellary region is characterised as one of the semi-arid zones of Karnataka, having only 508 mm of annual rainfall distributed over 35 rainy days.

The ill-distribution of rainfall creates at least 5 drought years in every decade. The average rainfall disitrbution shows that there is a total failure in Kharif season. However, some assured rainfall is received during September and October a better prospect which assumes for rabi season. This problem can be overcome to certain extent by scientific management of crops and water. This calls for detailed analysis of any important water resources issues. Keeping this in mind, an attempt is made in this paper to analyse short and long period rainfall data. The probability analysis of rainfall for shorter periods for identification of suitable periods for sowing, return period analysis for designing of soil and water conservation structures and determining the size of storage structures, the identification of number of various rainfall events for designing water harvesting system for crop and water management are carried out and presented in this paper.

The results of this study will help to plan the watershed management project in this and similar agro-climatic regions of Karnataka.

Key words — Conservation measures, Storage structures, Design of water harvesting system, Return period, Peak rate of run off, Grassed waterway, Agricultural watershed, Agro-climatic frequency analysis.

1. Introduction

Semi-arid zone of Karnataka experiences year to year as well as within the year fluctuations of seasonal rainfall, besides large variations in the time of the commencement, its inadequacy for sowing as well as in the distribution of dry periods within the crop growing season. Obviously, these are the major factors, influencing the high fluctuations in the crop yield noticed in the dry farming areas of the State. The forecasting of actual rainfall with its time of occurrence seems to be still eluding the scientists. So the information on short and long term probabilities based on data of the past years gains urgency. These provide an answer to identify patterns indicating the variations in rainfall which occur in general.

The problems mentioned above are further aggravated by improper and unscientific management of land and water resources. Without any conservation measures, the runoff from hills flows unchecked into the *nallahs* or gullies and on to the agricultural land accelerating erosion of valuable top fertile soil. Due to unregulated flow of water, the existing gullies are fast encroaching into adjoining agricultural lands. So this calls for a proper analysis of rainfall for different short and long duration periods for identification of suitable design rainfall values for construction of soil and water conservation structures, design of water harvesting systems such as location and size of farm ponds, storage structures etc in this as well as in the similar agroclimatic zones.

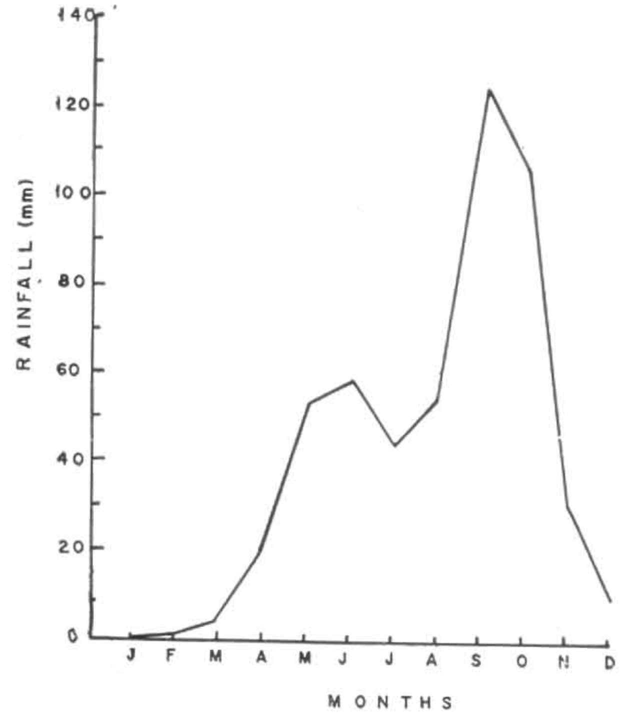

Fig. 1. Monthly mean values of rainfall

2. Utility of the study

Some practical examples of utility of this study are given here for arriving at the different soil conservation structures in agricultural land like bunds, waterways, farm ponds, etc expected rainfall (normally 10 years return period of daily rainfall) alongwith soil type, slope, etc should be considered for estimation of peak rate of runoff by any standard method like rational formula. The cross-section of the grassed waterway is arrived at by using the Manning's formula. The size of the farm pond can also be calculated from the expected runoff for a particular area, which can be calculated from expected rainfall of that area as shown in our study. In the same way, size of contour ditch, runoff collection tank can also be designed from the frequency of rainfall. Similarly for non-agricultural land such as hilly land, gully or nallah area, soil and water conservation structures such as drop and drop inlet structure, nallah bund, spill ways, etc are required to be designed. To design the spill ways, estimation of peak rate of runoff is necessary. Normally for agriculture watersheds having catchment area of a few hundred hectares, 6-hour duration of 50-year return period of rainfall is considered for estimating the peak rate of runoff for designing a spill way of a masonry drop structure. For small catchments having area of around 100 hectares, 1-hour duration of 50-year frequency of rainfall is considered. After estimating the peak rate of runoff, Weir formula is to be used for determining the spill way size. Similarly size of the diversion drain in the hilly area can also be designed based on the expected rainfall and runoff.

There are norms for choosing the different rainfall frequency values for designing different soil and water conservation structures described above (Singh *et al.* 1990). But the field engineer or designer can feel free to adopt any value as per his experience for a particular area in terms of agriculture, climate and importance of the structure and project.

Apart from designing of structure the rainfall information alongwith soil characteristics establish the criteria for choosing various forms of soil and water conservation measures for example, if the regions have less rainstorms but very intense and infiltration rate of the soil is low, it may be proposed for storage type of structures, so that stored water can be used for irrigation as and when required. On the contrary, if rainfall is not much intense and there is high infiltration rate, one may propose more of small gully control structures to delay the flow of runoff in the channel and create more opportunity for infiltration for recharging the surrounding wells to help irrigate the crops particularly in dryland areas, where shortage of water is acute.

3. Materials and method

The data are collected for the meteorological observatory of Soil Conservation Research Farm, Central Soil and Water Conservation Research and Training Institute, Research Centre, Bellary for the period 1956-1986. The farm is located at 15°09'N, 76° 51'E and 445 m above msl.

This region is classified as semi-arid zone of Karnataka with an average annual rainfall of 508 mm in 35 rainy days. Bellary region experiences scarcity conditions, in view of the non-availability of sufficient water either from rains or from other sources like irrigation canal and ground water for agriculture. Agricultural crops are generally sown during the rabi season with the onset of rains during middle of September. Fig.1 shows the monthly distribution of rainfall.

For optimum period of sowing, daily rainfall data of 31 years for the selected period from 21st August to 20th October (34th to 42nd meteorological week) and 15th May to 15th July (18 to 26th meteorological week) were taken up for the present study. To have a critical study to identify a minimum short period with the maximum probability the daily rainfall values were transformed into 4-day totals (selected tetrads as 14-17, 18-21 etc) and their corresponding values of of per cent of chance of occurrence were calculated. Further analysis was carried out to exactly pin point the tetrad which has maximum probability of rainfall occurrence. Daily rainfall values were totalled for sliding tetrad periods of 4 days such as 14-17, 15-18, 16-19 etc and their per cent chances of occurrence were calculated to identify the probable optimum period of sowing.

The rainfall data available have been subjected to return period analysis for different durations using double exponential Gumbel distribution (Anonymous 1972) given by:

$$X_T = \overline{X} - 0.45\ S + 0.78\ S\ Y_T$$

where, $Y_T = -\ \text{Log}_e\ [\text{Log}_e\ \{ (T/T-1) \}]$

S = Standard deviation of annual maximum rainfall series,

TABLE 1

Return period analysis of different long duration rainfall

Return period (year)	1D	2D	3D	5D	7D	Month	Annual
2	63	75	85	98	107	160	474
5	83	98	114	132	142	223	620
10	96	113	133	154	166	264	717
25	113	132	156	182	195	317	839
50	126	146	174	203	217	356	929
00	138	160	191	224	239	394	1019

D — Day (s). The values are in mm.

TABLE 2

Return period analysis of different short duration rainfall

Return period (year)	12H	6H	3H	1H
2	52	56	36	21
5	72	62	46	31
10	85	72	53	38
25	102	85	62	46
50	114	95	68	53
100	127	104	74	59

H—Hour (s).

$\bar{X}$ = Mean of the annual maximum rainfall series,

T = Any return period,

X_T = Rainfall amount for return period T.

Mean and standard deviation were calculated from annual maximum series of rainfall data. The annual maximum series had been arranged from long (1-day and more) and short (less than a day) rainfall data Adhikari *et al.* 1987).

After calculating the rainfall amounts for different eturn periods, ratios between short and long duration ainfall amounts have been worked out and these atios can be used to convert various long duration ainfall amounts (which are normally available) o short duration rainfall amounts for different return eriods (Adhikari *et al.* 1989).

The return period analysis was also conducted for olume of rainfall of the maximum 15 minutes and 30 ninutes is normally considered as the core of the rainfall vent to produce runoff and soil loss. (Adhikari *et al.* 991)

A total of 600 rain storms have been studied and esults are presented in this paper.

Results and discussion

4.1. *Optimum period of sowing*

To identify the optimum period of sowing tetrad r sliding tetrad having maximum probability of recording indicated amount of rainfall were calculated and resented in Figs. 2 and 3. It is seen from the figures at the tetrads 18-21 September (in the case of selected trad) and 17-20 September (in the case of sliding tetrad) ave the highest probability of occurrence of rainfall. o, 17-21 September can be recommended as a period itable for sowing of rainfed crops. The crops sown uring this period are likely to make use of the subseuent rains effectively up to the beginning of November nder normal climatic condition and result in maximum eld.

The same study was extended for kharif season also (from 15th May to 15th July) but no suitable period could be identified for sowing the crop. So this region has no possibility of kharif cropping under rainfed condition.

4.2. *Return period analysis*

The short duration (1, 3, 6 and 12 hrs) and long duration (1, 2, 3, 5, 7 day, monthly and annual) rainfall were subjected to return period analysis using Gumbel double exponential distribution method and the expected amounts of rainfall for the different return periods 2, 5, 10, 25, 50 and 100 year are presented in Tables 1 and 2.

Table 3 shows the factors for conversion of long duration rainfall into short duration rainfall. This information could be usefully utilized for agro-climatic regions similar to that of Bellary and where short duration rainfall data is required but not available. The long duration rainfall data is usually available for most of the places.

Return period analysis for the maximum 15 and 30 minutes rainfall intensity were also calculated and presented in Table 4. This is an useful additional factor, which help to develop prediction equation to predict expected runoff and soil erosion from rainfall.

The rainfall frequency values are necessary for crop planning, feasibility of water harvesting and reuse, design and planning of storage and gully control structures. It will also indicate the necessity of structures either at closer or at longer intervals. It will also help to identify the extent of soil erosion in the region, which will be helpful for planning soil and water conservation measures on watershed basis.

For designing gully control *cum* water harvesting structures, side channel spill way of *nallah* bund, grassed water way, bunds etc the frequency analysis of short duration rainfall are required. From Tables 1 and 2 any smaller or higher values could be taken as per the consideration of importance, cost and durability

TABLE 3

Factors for converting various long duration rainfall into short duration rainfall amounts for different return periods

P	1D	2D	3D	4D	5D	7D	Monthly
(a) To convert into 12 hrs or less duration rainfall							
2	0.82	0.69	0.61	0.57	0.53	0.49	0.33
5	0.87	0.74	0.63	0.58	0.55	0.51	0.32
10	0.89	0.75	0.64	0.59	0.55	0.51	0.32
25	0.90	0.77	0.65	0.60	0.56	0.52	0.32
50	0.91	0.78	0.66	0.60	0.56	0.53	0.32
100	0.92	0.79	0.67	0.61	0.57	0.53	0.32
(b) To convert into 6 hrs or less duration rainfall							
2	0.73	0.61	0.54	0.50	0.47	0.43	0.29
5	0.75	0.63	0.54	0.50	0.47	0.44	0.28
10	0.75	0.64	0.54	0.50	0.47	0.43	0.27
25	0.75	0.64	0.55	0.50	0.47	0.44	0.27
50	0.75	0.65	0.55	0.50	0.47	0.44	0.27
100	0.75	0.65	0.55	0.50	0.46	0.44	0.26
(c) To convert into 3 hrs or less duration rainfall							
2	0.57	0.48	0.42	0.39	0.37	0.34	0.23
5	0.55	0.47	0.40	0.37	0.35	0.32	0.21
10	0.55	0.47	0.40	0.37	0.34	0.32	0.20
25	0.55	0.47	0.40	0.36	0.34	0.32	0.20
50	0.54	0.47	0.39	0.36	0.34	0.31	0.19
100	0.54	0.46	0.39	0.35	0.33	0.31	0.19
(d) To convert into 1 hr or less duration rainfall							
2	0.33	0.28	0.25	0.23	0.21	0.20	0.13
5	0.37	0.32	0.27	0.25	0.24	0.22	0.14
10	0.40	0.34	0.29	0.26	0.25	0.23	0.14
25	0.41	0.35	0.30	0.27	0.25	0.24	0.15
50	0.42	0.36	0.31	0.28	0.26	0.24	0.15
100	0.43	0.37	0.31	0.28	0.26	0.25	0.15

D — Days(s), P — Return period in year

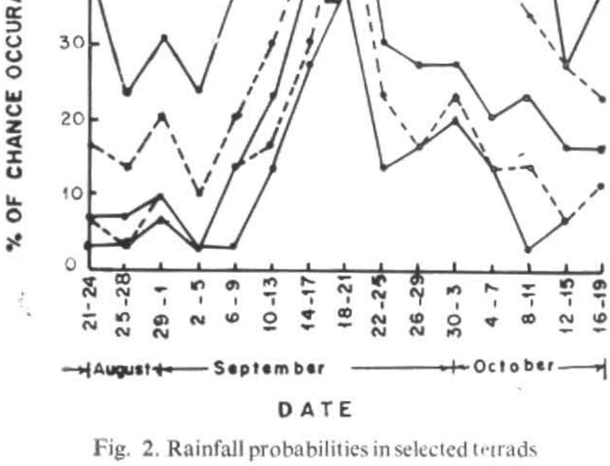

Fig. 2. Rainfall probabilities in selected tetrads

of structure and experience and judgement of the design engineer. The frequency analysis of other longer duration rainfall like 2, 3, 4, 5, 6, 7 day, monthly and annual are also important to account the probable moisture conservation, runoff and ground water potential and assessment of water balance of the watershed, which in turn may help to develop watershed management programme and planning of use of water resources.

4.3. *Identification of number of various rainfall events*

Figs. 4 and 5 show the number of events of daily and short duration rainfall respectively during different months. It is seen that in the month of September, daily rainfall equal to or more than 50, 60, and 70 mm occurred once in two, three and five years respectively. In respect of short duration rainfall analysis, 6 hrs rainfall of 40 or 50 mm in the month of September occurred once in two and six years respectively. Similarly for other months also, number of events can be calculated for any desired duration. Results will help to know the rainfall potential in general, for every month.

In addition to return period analysis the study is suitable to plan rainwater conservation measure and recycling for better crop production under this and similar agro-climatic conditions.

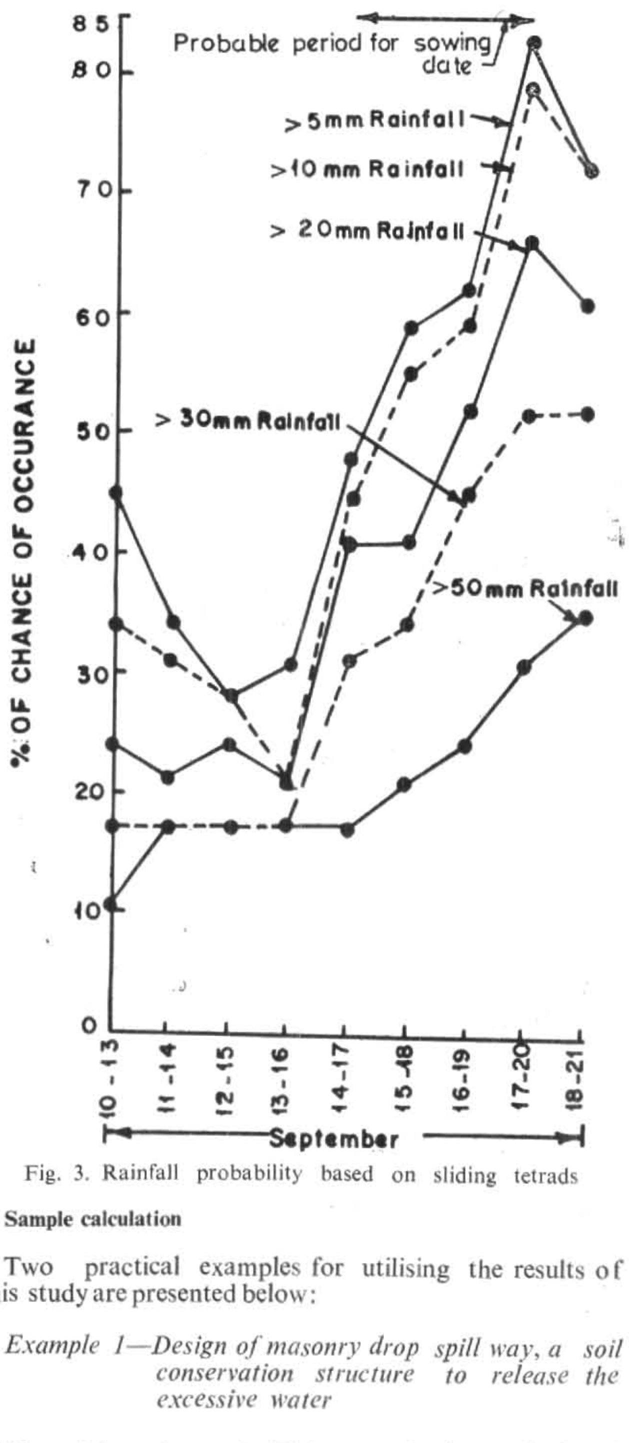

Fig. 3. Rainfall probability based on sliding tetrads

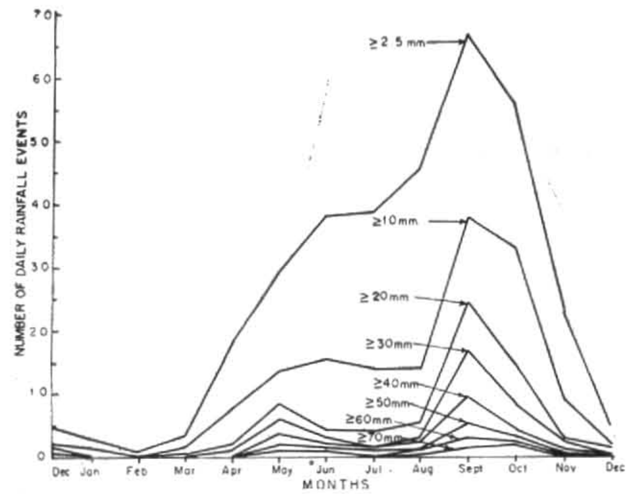

Fig. 4. Number of events of daily rainfall during different months (Bellary 1956–1986)

TABLE 4

Return period analysis for maximum 15 and 30 minutes rainfall intensity

Return period (year)	Maximum 15 min. intensity (mm/hr)	Maximum 30 min intensity (mm/hr)
2	84	59
5	103	75
10	116	85
25	132	97
50	143	107
100	155	116

5. Sample calculation

Two practical examples for utilising the results of this study are presented below:

Example 1—Design of masonry drop spill way, a soil conservation structure to release the excessive water

The catchment area is 50 hectares having agricultural land and some non-arable land. The time of concentration is 20 minutes. The peak rate of runoff is to be calculated as follows (Schwab *et al.* 1981) :

$$Q = \frac{C\ I\ A}{360}$$

where, Q = Peak rate of run off in cumec,
I = Intensity in mm/hr,
A = Catchment area in hectare, and
C = Runoff coefficient.

The factor intensity (I) can be obtained from the study conducted in this paper. From the Table 2, we can assume the value for 50-year return period of 1-hr duration rainfall, which is 53 mm. Now for 53 mm intensity and 20 minutes time of concentration, the design intensity is found as 120 mm/hr from standard diagram, the peak rate of runoff is :

$$Q = \frac{0.6 \times 120 \times 150}{360} = 30 \text{ cumec}$$

where, C is assumed 0.6 considering catchment characteristics (Singh *et al.* 1990).

The formula for rectangular spillway (Schwab *et al.* 1981) is given below :

$$Q = 1.71\ L\ H^{3/2}$$

where, Q = 30 cumec,
L = Length of the spillway,
H = Height of the spillway,
If H = 1.5 m, then

$$L = \frac{Q}{1.71\ H^{3/2}} = \frac{30}{1.71 \times 1.5^{3/2}} = 9.5 \text{ m}$$

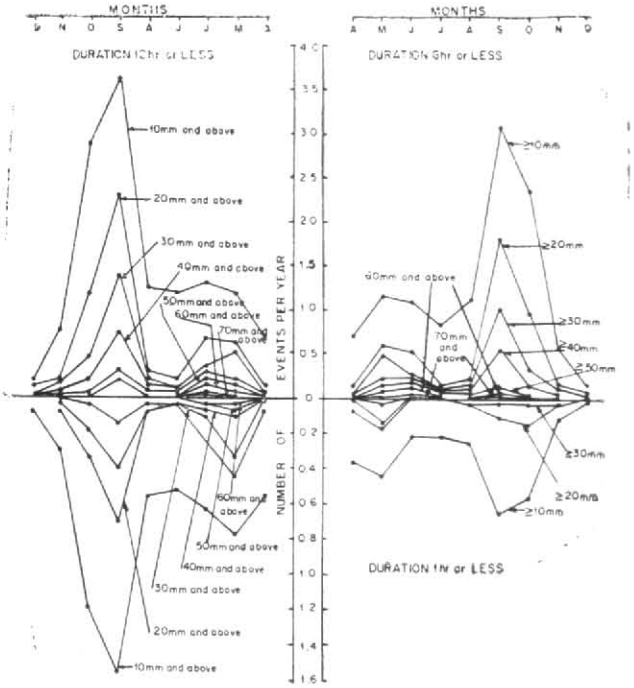

Fig. 5. Number of different short duration rainfall events for different months

So designed value of L and H of the spillway is 9.5 m and 1.5 m respectively. Construction can be made accordingly for the soil conservation structure at field level based on the value obtained by simply design procedure.

Example 2 — Designing a farm pond

It is quite understandable, since water flows down the slope the farm pond should be located at the lowest point of the drainage area. Consider a small farm area of 2 hec in Bellary region. One farm pond is required to be constructed at the end of the catchment. 10 years return period value of rainfall is normally choosen for a farm pond. From the Table 1, 10 years return period of daily rainfall is taken as 96 mm. If 50% of this rainfall is considered as runoff then total depth of water is 48 mm .

$$\text{Total volume of runoff} = 2 \times 10000 \times \frac{48}{1000} =$$

$$= 960 \text{ cumec}$$

(where, 2 hec = 2 × 10000 sq m)

Normally 1/3 of expected runoff water is recommended for determining the size of the pond.

$$\text{So size of the pond} = 1/3 \times 960 \text{ cumec}$$
$$= 320 \text{ cumec}$$

The above two simple examples show the utility of the results. The analysis brought out here can be applicable in all semi-arid zone of black soil region having annual rainfall between 500 mm and 700 mm for planning of soil and water conservation measures in watershed management project where limited information is available.

Acknowledgement

The authors are grateful to the Director, Central soil and Water Conservation Research and Training Institute, Dehradun for his keen interest in rainfall studies.

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